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Energy and Mines
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Aggregate Report AR86-1

The Aggregate Potential of Selected Paleozoic and Precambrian Rocks in Manitoba

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ABSTRACT

Mineral aggregates (sand, gravel and crushed rock) are those naturally occurring materials which are used by the construction industry to make cement, asphalt, ballast, plaster or stucco, and for fill purposes. Aggregates are essential, non-renewable mineral commodities that have no suitable substitute for many construction end uses. Aggregates are characterized by a low intrinsic value, a high bulk, and a delivered price that is highly sensitive to transportation costs.

There is a demonstrated need to manage and conserve Manitoba's aggregate resources, because of limited regional supplies, competing surface land uses restricting mineral development, and a general upgrading of technical requirements for the resource. Certain geographic areas within Manitoba, for example, the Interlake and Southeastern areas have a scarcity of high quality sand and gravel deposits. Crushed stone can act as a perfect substitute for sand and gravel when the quality and delivered price are competitive. In the areas mentioned above, rock quarries have been a source of high quality aggregate predominantly for highway construction.

Since the mid-seventies, provincial land use planning activities have created a situation in which technical input concerning mineral resources is required for municipal development plans and subsequent zoning by-laws. This report provides a data base for decision-making in order to evaluate the potential quality of carbonate and granitic rocks of the Precambrian, Ordovician, Silurian and Devonian geological formations as an aggregate resource.

INTRODUCTION

GENERAL STATEMENT

Mineral aggregates (sand, gravel, and crushed rock) are those naturally occurring materials which are used by the construction industry to make cement, asphalt, ballast, plaster or stucco, and for fill purposes. Aggregate is an essential mineral commodity required as a basic ingredient in most construction-related activities. This non-renewable resource, under present engineering technology, has no suitable substitute as a construction material. Aggregate is characterized by a low intrinsic value, and a high bulk; its delivered price is highly sensitive to transportation costs. The economics of production dictate that the mineral extraction and processing be located as close to the demand point (construction site) as economically practical. In Manitoba, during 1983, an estimated total of 13.9 million tons of aggregate was mined with a value of 39.6 million dollars.

In certain geographic regions in Manitoba, particularly in the Interlake region and southeastern Manitoba, sand and gravel scarcities have required the construction industry to substitute crushed stone for sand and gravel. Crushed stone has perfect substitutability with sand and gravel when their quality and delivered price are economically competitive.

Decisions concerning the opening or expansion of a quarry are subject to a number of technolgical, social, and economic considerations. Resource scarcity, caused by depletion of known sources, expanding technical requirements, and sterilization, has created a situation in which the Province recognizes the significance of aggregate resource management. The bedrock sampling and evaluation program was initiated during the field seasons of 1982 and 1983 to provide an assessment of the resource potential of Precambrian, Ordovician, Silurian and Devonian formations as sources of aggregate. The data generated by this program are used for two purposes, that is, as a guide in evaluating existing and potential quarry sites, and for land-use planning purposes for the preparation of municipal development plans, basic planning statements, and subsequent zoning by-laws.

OBJECTIVES

The objectives of the bedrock sampling program were:

(1) To evaluate the aggregate potential of selected Precambrian, Ordovician, Silurian and Devonian formations.

(2) To aid in identifying quarry locations in areas of sand and gravel scarcity.

(3) To provide a data base for the preparation of land-use planning guidelines in order to protect high quality aggregate sites from sterilization.

BEDROCK SAMPLING PROGRAM

Specifications for crushed stone are set by the American Society for Testing and Materials (ASTM) and the Canadian Standards Association (CSA). The specifications controlling quality are variable depending upon the intended end use of the material. Specifications are concerned with: resistance to abrasion and impact, alternate cycles of freezing and thawing or wetting and drying, chemical reactivity and deleterious constituents. Other factors important for some end uses include colour, water absorption, and specific gravity.

A laboratory investigation was conducted in accordance with ASTM and CSA specifications. The engineering tests conducted were:

1) Los Angeles Abrasion Test (C131)
   The Los Angeles test is used to measure degradation properties of mineral aggregates of standard grading resulting from a combination of abrasion, impact and grinding. The test is widely used as an indicator of the relative quality or competence of various sources of aggregate having similar mineral compositions (C131-81).
2) Sodium Sulphate Soundness Test (C188)
   The test determines the resistance of aggregate to disintegration by saturated solutions of sodium sulphate or magnesium sulphate. It furnishes information useful in judging soundness of aggregate subject to weathering action, particularly when adequate information is not available from service records of material exposed to actual weathering conditions.
3) Absorption Test (C127)
   The test involves the determination of bulk specific gravity, apparent specific gravity, and absorption of coarse aggregate (see C127-81). **Bulk specific gravity** is the characteristic generally used for calculation of the volume occupied by the aggregate in various mixtures containing water whereas **apparent specific gravity** pertains to the relative density of the solid material making up the constituent particles not including the pore space within the particles which is accessible to water.

The engineering requirements of aggregate for specific end uses are documented in the literature. In this study, an attempt to standardize the testing procedure for aggregate has been undertaken in order to predict the suitability of a particular source and to define the potential quality of each geologic member. The engineering tests, together with the qualifying specification (based upon ASTM and CSA standards), are listed in Table 1.

TABLE 1

GENERAL REQUIREMENTS FOR SELECTED END USES
OF BEDROCK AS A SOURCE OF AGGREGATE

	TEST	END USES OF AGGREGATE				
1.	LOS ANGELES ABRASION	CONCRETE AGGREGATE	BITUMINOUS AGGREGATE	BALLAST MATERIAL	BASE COURSE	SURFACING GRAVEL
	% Loss	35-50%	25-40%	12-25%	Type A 30-40% Type B 50-60%	50-60%
2.	MAGNESIUM SULPHATE SOUNDNESS					
	% Loss	12-18%	12-18%			
3.	ABSORPTION	1-2%	1-2%	0.5-1%		

ENGINEERING PROPERTIES OF AGGREGATES

GENERAL STATEMENT

Aggregate (sand, gravel, and crushed bedrock) can occupy up to 80 per cent of the total volume of concrete and asphalt. Consequently, the physical and chemical properties can significantly influence the engineering service of the material in Manitoba. The demand for aggregate as a construction material includes concrete and asphalt aggregate, railway ballast, economical fill (sub-base), and traffic gravel. Each end use possesses certain technologic requirements concerning physical and chemical durability, and should be considered prior to selecting a particular source. No particular rock or mineralogic type is necessarily required to be utilized for aggregate; however, certain mineralogical substances will cause problems in the field and do not conform to ASTM or CSA specifications.

Aggregates, when utilized as a construction material, should ideally be strong, durable, weather resistant, and free of deleterious constituents. Soft, friable, vuggy rock can limit the strength of the aggregate and, over time, subjected to normal wear and weathering, can significantly reduce the engineering performance. Consequently, dependent upon the end use requirements, aggregate should possess high quality standards when utilized for ballast, concrete or asphalt.

PHYSICAL PROPERTIES OF AGGREGATE

The following section provides a brief overview of the physical properties of aggregate that are significant in terms of evaluating a deposit for a particular use. Specifications for aggregate are normally concerned with: soundness; abrasion resistance; chemical reactivity; particle shape; gradation and deleterious constituents. Water absorption and specific gravity and other characteristics may be important for some end uses.

SHAPE

Aggregate shape can affect the workability of a construction material particularly when an aggregate source is utilized for concrete, asphalt, or ballast purposes. The shape of an aggregate particle depends upon several factors: presence of cleavage or bedding planes; lithology, degree of transport and subsequent depositional environment; and abrasion resistance (strength). A smooth, well rounded particle tends to be easier to work. For example, a well rounded aggregate utilized for concrete requires less water and cement paste whereas a crushed angular rock tends to become more "harsh" thereby requiring more cement and water for a mix.

SOUNDNESS

The soundness of aggregate is the ability of the aggregate to withstand the actions of weathering, particularly those due to the effects of repeated freezing-thawing and wetting-drying. The ability of the aggregate to resist weathering effects is determined to a large extent by the internal pore structure and composition (strength). A highly porous aggregate when subjected to the continual effects of the freeze-thaw or wetting and drying cycles will tend to disintegrate over an extended period of time.

ABRASION RESISTANCE

Abrasion resistance is the ability of rock to resist impact abrasion and is a measure of the strength (competence) or durability of aggregate. Carbonate rocks that have a high percentage of clays or have distinct bedding tend to be soft, friable and relatively weak whereas trap rocks (diorite, andesite, basalt, etc.) tend to be harder and more abrasion resistant.

DELETERIOUS SUBSTANCES

Deleterious substances are those materials that are present in aggregate that promote chemical or physical deterioration. Deleterious substances include chert, clay, silt, shale, sulphide minerals (pyrite, marcasite) organic impurities, coal, gypsum, and any other rocks highly susceptible to weathering. Lightweight particles including silt, shale, clay and organic material are considered to be unsound, and break down readily when exposed to the continual effects of weathering. In addition, pyrite, silica, gypsum and lead significantly affect the durability of concrete and asphalt due to the promotion of various chemical reactions within the material.

ABSORPTION

Absorption is the process by which a liquid penetrates and tends to fill permeable pores in a porous rock (ASTM C-125). The absorption of moisture in aggregate is controlled to a large degree by the size and internal pore structure within the aggregate particles. If the aggregate particle becomes saturated with moisture, under the continual effects of the freeze-thaw action, in time it will disintegrate.

AGGREGATE POTENTIAL OF SELECTED PRECAMBRIAN, ORDOVICIAN, SILURIAN AND DEVONIAN FORMATIONS

The objective of this section is to provide a summary of the findings of the bedrock sampling program. Representative samples of granitic and carbonate rock were collected from outcrops and quarries located in the Precambrian, Ordovician, Silurian and Devonian bedrock of southern Manitoba. The samples collected were tested, in accordance with CSA standards, and were evaluated for their potential in terms of concrete, asphalt, ballast, surfacing gravel, and for fill (sub-base material). The chemical properties of each sample, and a petrographic description, were also undertaken in order to aid in defining their suitability for aggregate (Appendices II and III). The samples collected are representative only of a certain portion of a geological member in a geographic locality, and the quality of the rock available within the geologic member in other localities may vary considerably from the results given.

PRECAMBRIAN

Two samples of Precambrian granite and related gneisses were tested for their aggregate potential (see Map AR86-1). The rock samples were collected from two intermittently active granite quarries located in southeastern Manitoba (L.G.D. of Alexander, R.M. of Lac du Bonnet). The rock has been used previously for riprap along the Winnipeg River and for local highway construction.

The physical properties and potential end uses of the Precambrian samples (CJ83-11, CJ83-12) are shown in Table 2. These granites suffered moderate L.A. abrasion loss and relatively low soundness loss; they are acceptable for fill, concrete, and asphalt aggregate. See Appendix II for additional petrographic detail.

TABLE 2

PHYSICAL PROPERTIES AND POTENTIAL END USES OF SELECTED PRECAMBRIAN GRANITES

Sample Number	CJ-83-11	CJ-83-12
Geologic Formation/Member	Archean	Archean
Location	SE1/4-33-15-11E	1-18-9E
Los Angeles Abrasion Loss %	36.4	22.3
Bulk Specific Gravity	2.62	2.67
Apparent Specific Gravity	2.66	2.69
Absorption	0.57	0.34
Porosity	1.49	0.90
Soundness Loss		
(a) 1 1/2" to 3/4"	0	0
(b) 3/4" to 1/2"	0	0
(c) 1/2" to 3/8:	0.2	0.5
Qualitative Analysis		
Total Number of Coarse Particles	71	63
Number of Particles Affected		
Type of Reaction		
Disintegrated		
Split Crumbled		
Cracked	1	
Flaked		
Other		
Potential End Uses		
Concrete Aggregate	Yes	Yes
Bituminous Aggregate	Yes	Yes
Base Course A	Yes	Yes
Base Course B	Yes	Yes
Surfacing Gravel	Yes	Yes
Ballast	-	Yes

ORDOVICIAN

Fifteen samples of carbonate rock (dolomite, limestone) were collected from various members of Ordovician strata in southern Manitoba. Three additional samples (CJ83-5, CJ83-6, CJ83-8) are from the northern part (Grand Rapids area) of the Ordovician outcrop belt where the geologic formations have not been subdivided. The rock samples were taken from existing quarries that are intermittently used for local highway construction.

Ordovician strata consist of the Winnipeg, Red River, Stony Mountain, and Stonewall Formations (see Table 3). The Ordovician Red River Formation has been subdivided into the Dog Head, Cat Head, Selkirk, and Fort Garry Members whereas the Stony Mountain Formation has been subdivided into the Gunn, Penitentiary, Gunton, and Williams Members. The Winnipeg Formation (sandstone) and the Williams Member (Stony Mountain Formation) were not tested for aggregate potential because of their low quality.

RED RIVER FORMATION: DOG HEAD MEMBER

Dolomitic limestone of the Dog Head Member of the Ordovician Red River Formation was tested for its potential suitability for aggregate (Table 3 and Table 4). The rock sample was taken from a rock quarry used for highway construction in 1977. The rock sample had a moderate L.A. abrasion loss but suffered a relatively high magnesium sulphate soundness loss making the rock unacceptable for concrete, asphalt, or ballast material. Further details concerning petrographic analyses and chemical properties are found in Appendices II and III.

CAT HEAD MEMBER

One sample (CJ82-16) of dolomite of the Cat Head Member of the Ordovician Red River Formation was tested for aggregate potential. The rock was sampled from an intermittently active highway quarry located in sec. 22-24-4E (see Table 3 and Table 4). The rock sample had both a moderate L.A. abrasion loss and a moderate magnesium sulphate loss making it suitable for most uses outlined excluding ballast.

SELKIRK MEMBER

Three bulk samples of dolomitic limestone from existing quarries (CJ82-13, CJ82-14), CJ82-15) were tested for their aggregate potential (see Table 3 and Table 4). Sample CJ82-13 was sampled from a quarry located near Winnipeg Beach that exposes granular dolomite. The sample suffered moderate L.A. abrasion loss and magnesium sulphate loss making it marginally acceptable for concrete and asphalt. Samples CJ82-14 and CJ82-15 were taken from the Tyndall stone quarries near Garson. Samples suffered relatively high L.A. abrasion loss making them marginally acceptable for concrete aggregate and unacceptable for bituminous aggregate and ballast; the rock is dolomitic limestone.

FORT GARRY MEMBER

Two samples (CJ82-11, CJ82-12) of dolomite of the Fort Garry Member of the Ordovician Red River Formation were taken from a rock quarry located northeast of Stony Mountain. Sample CJ82-11 is from the Upper Fort Garry Member whereas CJ82-12 is from the Lower Fort

TABLE 3

STRATIGRAPHY AND LITHOLOGY OF ORDOVICIAN CARBONATES
(modified after McCabe and Barchyn, 1982)

GEOLOGIC FORMATION	MEMBER	BASIC LITHOLOGY	SAMPLE NUMBER	COMMENTS
Stonewall		Dolomite, pale yellowish brown, thin bedded, variably fossiliferous	CJ82-3 CJ82-4	Quarry - Stonewall Formation (Upper) Quarry - Stonewall Formation (Lower)
Stony Mountain	Williams	Argillaceous sandy silty dolomite, commonly medium greyish red		Low quality - No sample taken
	Gunton	Dolomite, pale yellowish brown, faintly mottled, sparsely fossiliferous, medium to thin bedded, in part nodular to intraclastic	CJ82-5 CJ82-6 CJ82-7 CJ82-8	Quarry Quarry Quarry Quarry
	Penitentiary	Argillaceous dolomite, mottled shades orangy to reddish grey, commonly burrowed texture, variable fossiliferous with fossil solution porosity	CJ82-9	Quarry
	Gunn	Interbedded grey fossiliferous fragmental limestone and reddish to purplish grey burrow-mottled calcareous and dolomitic shale	CJ82-10	Quarry
Red River	Fort Garry	Dolomite. Lower part of unit microcrystalline dense sublithographic light grey to reddish mottled, in part finely laminated. Passes upward to finely crystalline, massive to thick bedded cherty dolomite. Thin medial shale/breccia zone	CJ82-11 CJ82-12	Quarry - Upper Quarry - Lower
	Selkirk	Dolomitic limestone, burrow-mottled, light to medium yellowish brown, biomicrite, in part highly fossiliferous "Tyndall Stone"	CJ82-13 CJ82-14 CJ82-15	Quarry Quarry Quarry
	Cat Head	Dolomite, pale yellowish brown finely crystalline, moderately granular, scattered fine relict fossil fragments, medium bedded, numerous white chert nodules	CJ82-16	Quarry
	Dog Head	Mottled dolomitic limestone, slightly argillaceous, variably fossiliferous biomicrite	CJ82-17	Quarry
Winnipeg		Interbedded sandstone and shale	No Sample Taken	

TABLE 4

PHYSICAL PROPERTIES AND POTENTIAL END USES OF ORDOVICIAN CARBONATES

Sample Number	CJ82-3	CJ82-4	CJ82-5	CJ82-6	CJ82-7	CJ82-8	CJ82-9	CJ82-10	CJ-82-11
Geologic Formation/Member	Upper Stonewall	Lower Stonewall	Stony Mtn. Gunton	Stony Mtn. Gunton	Stony Mtn. Gunton	Stony Mtn. Gunton	Stony Mtn. Penitentiary	Stony Mtn. Gunn	Red River Fort Garry (Upper)
Location	30,31-13-2E	30,31-13-2E	28-12-2E	11-13-2E	13,14-32-13-2E	28-15-2E	12-13-2E	14-13-2E	27-13-3E
Los Angeles Abrasion Loss %	27.0%	23.8%	27.5%	27.7%	29.3%	30.3%	58.0%	45.7%	32.7%
Bulk Specific Gravity	2.56	2.61	2.59	2.62	2.59	2.62	2.38	2.56	2.52
Apparent Specific Gravity	2.77	2.76	2.77	2.76	2.75	2.75	2.76	2.74	2.73
Absorption	3.0%	2.2%	2.5%	1.9%	2.2%	1.9%	5.6%	2.6%	3.1%
Porosity	7.6%	5.6%	6.4%	5.0%	5.8%	5.0%	13.7%	6.6%	7.7%
Soundness Loss									
(a) 1 1/2" to 3/4"	10.8%	6.4%	17.1%	4.5%	12.7%	9.6%	100%	69.5%	15.3%
(b) 3/4" to 1/2"	10.9%	6.6%	16.5%	5.2%	13.3%	10.3%	100%	69.8%	19.8%
(c) 1/2" to 3/8:	22.9%	16.2%	27.0%	8.5%	20.9%	15.0%	100%	79.8%	30.7%
Qualitative Analysis									
Total Number of Coarse Particles	59	63	64	62	75		62	54	60
Number of Particles Affected									
Type of Reaction									
Disintegrated			39						
Split									
Crumbled									
Cracked	24	8	3	2			16	24	22
Flaked	9								
Other									
Potential End Uses									
Concrete Aggregate	Marg-Poor	Yes	-	Yes	Marg.	Yes	-	-	Marg.
Bituminous Aggregate	Marg-poor	Yes	-	Yes	Marg.	Yes	-	-	Marg.
Base Course A	Yes	Yes	Yes	Yes	Yes	Yes	-	-	Yes
Base Course B	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Surfacing Gravel	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ballast	Marg-Poor	Marg.	Marg-Poor	Marg	-	-	-	-	-

Sample Number	CJ-82-12	CJ82-13	CJ82-14	CJ82-15	CJ82-16	CJ82-17	CJ83-5	CJ83-6	CJ83-8
Geologic Formation/Member	Red River Fort Garry (Lower)	Red River Selkirk	Red River Selkirk	Red River Selkirk	Red River Cat Head	Red River Dog Head	Red River	Stony Mtn.	Red River
Location	27-13-3E	6-18-4E	3-13-6E	3-13-6E	22-24-4E	25-25-6E	22-60-12W	2-60-12W	SW1/4-30-64-15W
Los Angeles Abrasion Loss %	32.5%	41.2%	51.1%	48.4%	37.1%	32.7%	25.8%	36.1%	22.9%
Bulk Specific Gravity	2.64	2.51	2.38	2.42	2.34	2.60	2.75	2.59	2.82
Apparent Specific Gravity	2.80	2.71	2.64	2.65	2.64	2.74	2.83	2.79	2.86
Absorption	2.2%	3.0%	4.0%	3.5%	4.8%	2.0%	1.06%	2.71%	0.50%
Porosity	5.9%	7.5%	9.6%	8.5%	11.2%	5.2%	2.96%	7.02%	1.14%
Soundness Loss									
(a) 1 1/2" to 3/4"	23.8%	8.0%	8.0%	3.5%	7.4%	22.8%	2.2%	7.9%	1.9%
(b) 3/4" to 1/2"	27.2%	8.3%	10.4%	12.2%	7.3%	21.5%	1.3%	9.1%	1.7%
(c) 1/2" to 3/8:	34.2%	16.8%	18.6%	21.3%	18.5%	47.7%	2.2%	11.5%	2.5%
Qualitative Analysis									
Total Number of Coarse Particles	68	59	67	70	62	59	56	61	52
Number of Particles Affected									
Type of Reaction									
Disintegrated					6	1			
Split			2				2		
Crumbled			7			6			
Cracked	39	20	9	18	18	25	7	38	20
Flaked									
Other			8		14	6	1	3	19
Potential End Uses									
Concrete Aggregate	-	Marg.	Marg.	Marg.	Marg.	Yes	-	Yes	Yes
Bituminous Aggregate	-	Marg.	Marg.	-	-	Yes	-	Yes	Yes
Base Course A	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Base Course B	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Surfacing Gravel	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ballast	-	-	-	-	-	-	Marg-Poor	-	Yes

Garry member. Both samples suffered relatively high L.A. abrasion losses; however, soundness losses were low enough to classify the rock as acceptable for Type A or B base course and surfacing gravel (see Table 3 and Table 4).

STONY MOUNTAIN FORMATION: GUNN MEMBER

One sample of purplish calcareous shale of the Gunn Member of the Ordovician Stony Mountain Formation was tested for its aggregate potential. The sample was taken from the City of Winnipeg Primary Materials quarry located near Stony Mountain. The Gunn Member experienced high L.A. abrasion loss and soundness loss making it unacceptable for concrete, asphalt, and ballast material. See Table 3 and Table 4 for further details.

PENITENTIARY MEMBER

One sample (CJ82-9) of yellowish orange dolomite of the Penitentiary Member of the Ordovician Stony Mountain Formation was tested for its suitability for aggregate. The sample broke down completely during the Magnesium Sulphate Soundness Test (see Table 4) and experienced very high L.A. abrasion loss. This material was found to be suitable for Type B base course and for surfacing gravel.

GUNTON MEMBER

Four samples (CJ82-5, CJ82-6, CJ82-7, CJ82-8) of dolomite of the Gunton Member of the Ordovician Stony Mountain Formation were taken from active quarries located in the R.M. of Rockwood, and were tested for their aggregate potential. The Gunton member consists of a pale yellowish brown dolomite that has been widely used for aggregate both locally and in the City of Winnipeg. The Gunton Member, in general, suffered both moderate L.A. abrasion loss and sulphate loss, and is suitable for most end uses outlined in Table 4 excluding ballast. One sample, CJ82-5, experienced high magnesium sulphate loss making it unacceptable for concrete and bituminous uses.

STONEWALL FORMATION

Two samples of the Ordovician Stonewall Formation (CJ82-3, CJ82-4) were tested for their aggregate potential. The Stonewall Formation consists of a pale yellowish brown dolomite. The samples were taken from a rock quarry located near Stonewall with sample CJ82-3 being representative of the Upper Stonewall Formation and CJ82-4 representative of the Lower Stonewall Formation. The Upper Stonewall suffered moderate L.A. abrasion loss but experienced high sulphate loss thereby making it marginally acceptable for concrete and asphalt aggregate. The Lower Stonewall suffered relatively low L.A. abrasion loss and sulphate loss making it acceptable for all uses outlined in Table 4.

SILURIAN

Five bulk samples of Silurian carbonate bedrock were evaluated for their aggregate potential, and were taken from quarries located along Provincial Highway No. 6 as well as from a quarry located near Inwood (map — in pocket). The Silurian strata in southern Manitoba have been subdivided into six geologic formations including the Fisher Branch, Inwood, Moose Lake, Atikameg, East Arm, and Cedar Lake Formations. Representative samples of the Inwood, Moose Lake, and Cedar Lake Formations were taken from quarries located throughout the Silurian outcrop belt.

INWOOD FORMATION

Two samples of the Silurian Inwood Formation (CJ82-1, CJ82-2) were tested for their aggregate potential. The Silurian Inwood formation consists of a pale yellowish brown microcrystalline dolomite with sample CJ82-1 being representative of the upper Inwood Formation and CJ82-2 being representative of the lower Inwood Formation (see Table 5). Sample CJ82-1 suffered a moderately high L.A. abrasion loss with a moderately high soundness loss and would be marginal, at best, for use in concrete or asphalt aggregates (see Table 6). Sample CJ82-1 has engineering properties similar to sample CJ82-2, and is marginally acceptable for concrete and asphalt aggregate. Both samples are suitable however for Base Course A or B and for surfacing gravel. See Appendix III for chemical properties and Appendix II for additional petrographic detail.

MOOSE LAKE FORMATION

One sample (CJ83-7) of the Silurian Moose Lake Formation was tested for its aggregate potential. The Silurian Moose Lake Formation consists of a white to pale yellowish brown dolomite that is finely crystalline. Sample CJ83-7 suffered a moderate L.A. abrasion loss but experienced a high sulphate loss making it suitable for Base Course A and B as well as surfacing gravel (Table 6).

CEDAR LAKE FORMATION

Two samples (CJ83-1, CJ83-4) of the Silurian Cedar Lake Formation were tested for their aggregate potential. The Cedar Lake Formation consists of a white to pale yellowish brown dolomite (Table 5). Sample CJ83-4 suffered a moderate L.A. abrasion loss but experienced a very low sulphate loss making it acceptable for all uses outlined in Table 6 excluding ballast. Sample CJ83-7 had a moderate L.A. abrasion loss but suffered a high sulphate loss making it acceptable for Base Course A and B as well as surfacing gravel.

DEVONIAN

Four samples of carbonate rock of Devonian age were tested for their suitability for aggregate. The Devonian strata in southern Manitoba have been subdivided into eight geologic formations including the Ashern, Elm Point, Winnipegosis, Dawson Bay, Souris River, Duperow, Nisku, and Lyleton (Table 7). The latter three occur only in the subsurface. Representative samples of the Winnipegosis, Dawson Bay, and Souris River Formations were taken from outcrops and quarries located in the Devonian outcrop belt (see Map AR86-1 in pocket).

WINNIPEGOSIS FORMATION

One carbonate sample (CJ83-3) of the Devonian Winnipegosis Formation was tested for its aggregate potential. The Winnipegosis Formation consists of light yellowish brown dolomite. Sample CJ83-3 suffered moderate L.A. abrasion loss and sulphate loss but the absorption percentage (see Table 8) was high. The rock is suitable for Base Course A and B as well as surfacing gravel.

DAWSON BAY FORMATION

One sample (CJ83-2) of limestone of the Dawson Bay Formation was tested for its aggregate potential. The Dawson Bay Formation consists of a brownish buff limestone. Sample CJ83-2 suffered a moderate L.A. abrasion loss with a low sulphate resistant loss making it acceptable for all end uses outlined in Table 8 excluding ballast.

SOURIS RIVER FORMATION

Two bulk samples (CJ83-9, CJ83-10) of the Souris River Formation were tested for their aggregate potential. Sample CJ83-9 suffered moderate L.A. abrasion loss and low soundness loss making the rock acceptable for all uses listed in Table 8 excluding ballast. Sample CJ83-10 suffered moderate L. A. abrasion loss but experienced a high sulphate soundness loss making it suitable for Type A and B base course and traffic gravel only.

CONCLUSION

Eighteen bulk samples of carbonate rock of Ordovician age, five Silurian carbonate samples, and four Devonian samples were tested, in accordance with ASTM standards, for their aggregate potential. Of the Ordovician samples the Stonewall Formation and the Gunton Member of the Stony Mountain Formation appear to have the highest potential for aggregate whereas with the Silurian and Devonian Formations further testing should be conducted before drawing any general conclusions. As previously mentioned, the aggregate potential of any geologic member may vary considerably in a different geographic locality due to a facies change or other factors.

TABLE 5

STRATIGRAPHY, AND LITHOLOGY OF SILURIAN CARBONATES
(modified after McCabe and Barchyn (1982))

GEOLOGIC FORMATION	BASIC LITHOLOGY	SAMPLE NUMBER	COMMENTS
Cedar Lake	Dolomite, white to pale yellowish brown, microcrystalline dense sublithographic, thin bedded, in part stromatolitic	CJ83-1	Quarry
		CJ83-4	Quarry
East Arm	Dolomite, pale yellowish brown, sandy to silty and argillaceous, in part oolitic		
Atikameg	Dolomite, medium orangy brown, fine to medium crystalline, moderately granular, massive, vuggy, sparsely fossiliferous		
Moose Lake	Dolomite, white to pale yellowish brown, finely microcrystalline dense sublitho-graphic	CJ83-7	Quarry
Inwood	Dolomite, pale yellowish brown, micro-crystalline, moderately granular, in part stromatolitic, in part argillaceous with sandy and silty interbeds	CJ82-1	Quarry - Upper Inwood
		CJ82-2	Quarry - Lower Inwood
Fisher Branch	Dolomite, pale yellowish buff finely crystalline, slightly granular, fossili-ferous zones		

TABLE 6
PHYSICAL PROPERTIES AND POTENTIAL END USES
OF SILURIAN CARBONATES

Sample Number	CJ82-1	CJ82-2	CJ83-1	CJ83-4	CJ83-7
Geologic Formation/Member	Interlake Group Upper Inwood	Interlake Group Lower Inwood	Cedar Lake	Cedar Lake	Moose Lake
Location	11-18-1W	11-18-1W	1.s.4-7-23-5W	NW1/4-19-31-9W	NW1/4-30-48-13W
Los Angeles Abrasion Loss %	36.4%	33.5%	44.1%	29.0%	30.4%
Bulk Specific Gravity	2.58	2.43	2.54	2.73	2.73
Apparent Specific Gravity	2.82	2.77	2.69	2.81	2.82
Absorption	3.3%	5.1%	2.25%	1.03%	1.18%
Porosity	8.6%	12.3%	5.71%	2.80%	3.23%
Soundness Loss					
(a) 1 1/2" to 3/4"	9.7%	7.9%	1.1%	1.3%	15.6%
(b) 3/4" to 1/2"	11.6%	17.1%	0.6%	1.1%	15.9%
(c) 1/2" to 3/8:	26.9%	29.9%	7.3%	3.3%	26.6%
Qualitative Analysis					
Total Number of Coarse Particles	65	71	55	53	44
Number of Particles Affected					
Type of Reaction					
Disintegrated					
Split		1			
Crumbled		6			
Cracked	19	2	1	7	14
Flaked	9		6	1	7
Other					
Potential End Uses					
Concrete Aggregate	Marg	Marg.	-	Yes	-
Bituminous Aggregate	Marg	Marg.	-	Yes	-
Base Course A	Yes	Yes	Yes	Yes	Yes
Base Course B	Yes	Yes	Yes	Yes	Yes
Surfacing Gravel	Yes	Yes	Yes	Yes	Yes
Ballast-	-	-	-	-	-

TABLE 7

STRATIGRAPHY AND LITHOLOGY OF DEVONIAN CARBONATES
(modified after McCabe and Barchyn (1982))

GEOLOGIC FORMATION	BASIC LITHOLOGY	SAMPLE NUMBER	COMMENTS
Lyleton	Red siltstone and shale dolomitic		
Nisku	Limestone and dolomite, yellow-grey fossiliferous, porous, some anhydrite		
Duperow	Limestone and dolomite, argillaceous and anhydritic in places		
Souris River	Cyclical shale, limestone, and dolomite, anhydrite	CJ83-9 CJ83-10	Quarry Quarry
Dawson Bay	Limestone and dolomite, porous, anhydrite - local shale red and green	CJ83-2	Quarry
Winnipegosis	Dolomite, light yellowish brown - reefy	CJ83-3	Quarry
Elm Point	Limestone, fossiliferous, high calcium		
Ashern	Dolomite and shale, brick red		

TABLE 8

PHYSICAL PROPERTIES AND POTENTIAL END USES
OF DEVONIAN CARBONATES

Sample Number	CJ83-2	CJ83-3	CJ83-9	CJ83-10
Geologic Formation/Member	Dawson Bay	Winnipegosis	Souris River	Souris River
Location	13-24-10W	3-21-24-10W	14,15-9-31-18W	1-5-33-19W
Los Angeles Abrasion Loss %	29.4%	35.1%	30.4%	38.7%
Bulk Specific Gravity	2.63	2.42	2.65	2.55
Apparent Specific Gravity	2.69	2.68	2.71	2.78
Absorption	0.94%	4.02%	0.83%	3.22
Porosity	2.47%	9.73%	2.19%	8.20%
Soundness Loss				
(a) 1 1/2" to 3/4"	5.9%	3.7%	0.4%	44.7%
(b) 3/4" to 1/2"	8.3%	2.0%	0.5%	29.0%
(c) 1/2" to 3/8:	14.0%	4.6%	4.8%	42.7%
Qualitative Analysis				
Total Number of Coarse Particles	48	51	47	60
Number of particles affected				
Type of Reaction				
Disintegrated				
Split Crumbled				
Cracked			2	21
Flaked	4	5		14
Other				
Potential End Uses				
Concrete Aggregate	Yes	-	Yes	-
Bituminous Aggregate	Yes	-	Yes	-
Base Course A	Yes	Yes	Yes	Yes
Base Course B	Yes	Yes	Yes	Yes
Surfacing Gravel	Yes	Yes	Yes	Yes
Ballast	-	-	-	-

REFERENCES

American Standards for Testing and Materials, 1982; Concrete and Mineral Aggregates, Philadelphia.

American Standards for Testing and Materials, 1982; Road, Paving, and Bituminous Materials, Traveled Surface Characteristics, Philadelphia.

Baillie, A.D.

1951: Silurian geology of the Interlake area, Manitoba; Manitoba Mines Branch, Publication 50-1.

1952: Ordovician geology of Lake Winnipeg and adjacent areas, Manitoba; Manitoba Mines Branch, Publication 51-6.

1953: Devonian system of the Williston basin area, Manitoba; Manitoba Mines Branch, Publication 52-5.

Bannatyne, B.B.

1979: Dolomite resources of the southern Interlake area; in Manitoba Mineral Resources Division, Report of Field Activities 1979.

Bannatyne, B.B. and Jones, C.W.

1979: Preliminary geology maps of the southern Interlake region; Mineral Resources Division, Manitoba; Map Nos. 1979DR-7; 1979DR-8; 1979DR-9; 1979DR-10.

Canadian Standards Association

1977: Concrete materials and methods of concrete construction; National Standards of Canada, Rexdale, Ontario.

Dolar-Mantuani, L.

1983: Handbook of Concrete Aggregates: a Petrographic and Technological Evaluation; National Research Council.

Goldbeck, A.T.

1954: Crushed stone production; in Journal of the American Concrete Institute, vol. 25, no. 9.

Goudge, M.F.

1944: Limestones of Canada, their occurrence and characteristics, Part V, Western Canada, Report No. 811; Mines Branch, Ottawa.

Hay, W.

1953: Railroad engineering; John Wiley and Sons, New York.

Jones, C.W.

1982: The economic effects of urbanization on the crushed stone industry in the Rural Municipality of Rockwood, Manitoba; Published Master's Practicum, Natural Resources Institute, University of Manitoba.

1983: Aggregate resource management in Manitoba; in Manitoba Mineral Resources Division, Report of Field Activities 1983.

1984: Aggregate resource management in Manitoba; in Manitoba Mineral Resources Division, Report of Field Activities 1984.

1985: Aggregate resource management in Manitoba; in Manitoba Mineral Resources Division, Report of Field Activities 1985.

Jones, C.W. and Bannatyne, B.B.

1982: Bedrock evaluation for aggregate; in Manitoba Mineral Resources Division, Report of Field Activities 1982.

1983: A preliminary assessment of selected bedrock resources for aggregate potential; in Manitoba Mineral Resources Division, Report of Field Activities 1983.

Krynine, D. and Judd, W.

1957: Principles of engineering geology and geotechnics; McGraw-Hill Company, Toronto.

MacLaren, J.F.

1980: Mineral aggregate study of the southern Interlake region; Report submitted to Mineral Resources Division, Manitoba Department of Energy and Mines.

McLean, A.C. and Gribble, C.D.

1979: Geology for Civil Engineers; George Allen and Unwin Co., London.

Mindess, S. and Young, J.

1981: Concrete; Prentice-Hall Inc.; Englewood Cliffs, New Jersey.

Oosterveen, J.

1981: A preliminary study of the engineering properties of Ordovician and Silurian limestones of southern Manitoba; Unpublished B.Sc. thesis, University of Manitoba.

Yoder, E.J. and M.W. Witczak

1975: Principles of pavement design; John Wiley and Sons, Inc., New York.

APPENDIX I

ENGINEERING REQUIREMENTS FOR SELECTED END USES OF AGGREGATE

END USES OF AGGREGATE

BALLAST

Ballast is gravel or crushed rock laid in a railway bed underlying the track and performs several essential functions as a construction material. Most significantly ballast supports the load of the track and railroad traffic permitting the overlying pressure from the load to be uniformly transmitted into the subgrade. Ballast is normally a coarse aggregate (3/4" to 3 1/2") of irregularly shaped particles; these interlock with the ties, providing resistance to disturbing forces. Critical requirements of ballast include impeding vegetation growth, providing adequate drainage, minimizing the effect of frost heaving, and absorbing the overlying stress.

Ballast ideally should possess physical characteristics of strength, durability and stability, as well as economic availability. Ballast should be able to resist the impact of overlying stress loadings as well as resist abrasion and physical weathering. Abrasion occurs when ballast's interlocking particles rub against each other as they react elastically to overlying pressures whereas weathering, induced predominantly as an effect of continual freeze-thaw cycles, causes disintegration of the aggregate.

A variety of ballast materials are available in a region; however, in certain instances only a few will meet the required ASTM specification. The highest potential ballast source is crushed bedrock including limestone, granite, trap rocks, etc. which are generally strong and durable. Crushed bedrock is often preferred over gravel for ballast due to the uniformity of bedrock; in addition, naturally occurring gravel has been subjected to greater weathering. One other consideration is the type and quantity of deleterious substances including clay, shale, organic material, and chert.

CONCRETE

Mineral aggregates occupy approximately 70 to 80 per cent of the volume of concrete and consequently can significantly influence concrete's physical properties. No particular rock type is required for concrete aggregate and, in most instances, a local aggregate deposit can be found that will conform to ASTM specifications. Concrete aggregates are classified by petrography, specific gravity, crushed/naturally processed, size (sieve analysis) and chemical reactivity.

Aggregate utilized for concrete should conform to ASTM specifications considering specific gravity, physical durability (crushing strength), chemical durability (soundness) and absorption.

Concrete aggregate ideally should be hard, strong, durable, and free of deleterious substances. Soft, vuggy rocks containing deleterious particles can limit strength and wear resistance of concrete and in the long term, significantly affect durability. One of the most important properties of aggregate is its ability to resist the weathering effects of freeze-thaw and alternating wetting and drying. Aggregate, particularly carbonate, has an internal pore structure that permits saturation under relatively high moisture conditions. Saturated aggregate is subject to intense freeze-thaw action which causes expansion of water thereby increasing internal pressure. In time, over several thousand repeated cycles the aggregate tends to disintegrate causing popouts. Impurities of clay, shale, and chert with a low specific gravity in limestone also tend to cause popouts.

BITUMINOUS AGGREGATE

Asphalt (bituminous aggregate) has several applications as a construction material including end uses such as road construction (surface course), parking lots, airport runways, etc. The purpose of surface course is to provide a safe and smooth ride; over time it is subject to significant abrasion caused by horizontal forces of the wheels of automobiles or aircraft. The surface course should possess properties of skid resistance, durability, impermeability to moisture, and resistance to fracturing; it should be relatively smooth in order to reduce impact abrasion. The stress of the vehicle is transmitted to the underlying base course, and consequently the underlying course must also be durable in order to avoid an increasing quantity of fines that reduces the drainage capacity of the course.

The aggregate used for asphalt should possess properties of abrasion resistance, freeze-thaw resistance, strength, and low absorption. Also, rocks containing a high percentage of silica or carbonates containing accessory minerals such as clay and silt should be avoided as an asphalt aggregate. Silica encourages water-sorption and has a low bitumen sorption whereas clay minerals tend to promote cracking, shrinking, expansion, and parting. If limestone is used an an asphalt aggregate it should be at least 70 per cent by weight calcium or magnesium carbonate.

BASE COURSE

Base course is the layer of material (aggregate) located immediately below the wearing surface of the pavement and has several functions, according to the type of overlying pavement, including protection against frost action, drainage of water, increased structural capacity, prevention of volume change, and expedition of construction. Base courses are utilized under asphalt pavement in order to increase the supporting capacity of the pavement by added resistance to fatigue; by building up relatively thick layers of aggregate it is possible to distribute the load through relatively thin layers of pavement. One critical function of base course is to provide efficient drainage of water in order to minimize the effect of frost action.

To provide the above technical requirements the aggregate utilized for base course is ideally well graded, contains no fines, has non-frost susceptibility, and is strong in order to resist deformation. Aggregate that has been crushed provides more stability than round grained materials due to the added grain interlock. Crushed aggregate also provides for better permeability and therefore is readily drained. The economics of material availability determines whether crushed aggregate or pit run sand and gravel is used as base course.

APPENDIX II
PETROGRAPHIC DESCRIPTIONS OF BEDROCK SAMPLES

PETROGRAPHIC DATA

CJ-82-1 Silurian Inwood Formation — Inwood Quarry.
- Upper 2 metres in north wall of central quarry; pale creamy white dense micritic porcelaneous dolomite.
- Rock is highly fractured, hard, and brittle.
- Small pinpoint oxidation stains cover the fractured surface.
- The rock fractures irregularly in a conchoidal fashion and parts along fracture planes.

CJ-82-2 Silurian Inwood Formation — Inwood Quarry
- Lower 2 metres in north wall of quarry; thin bedded, finely crystalline buff dolomite, including stromatolitic mounds; lower layer is finely fragmental dolomite.
- The rock has a fine pinpoint porosity with isolated vugs.
- The fracturing is irregular with no preferred orientation.

CJ-82-3 Ordovician Stonewall Formation — Stonewall Quarry
- 2.65 metres from northwest quarry, Stonewall; medium to thick bedded buff to yellowish buff dolomite, above 1 metre layer of thin bedded rubbly dolomite.
- No visible bedding, fracturing or jointing planes.
- When crushed the rock fractures irregularly with some edges taking on a crumbly appearance.

CJ-82-4 Ordovician Stonewall Formation — Stonewall Pit
- 2.1 metres of mottled grey and orange-grey dolomite, abundant porosity, below 0.35 metre layer of purplish red and grey argillaceous dolomite and shale, from pit in floor of quarry.
- There is no preferred alignment of fractures or joints and the rock breaks in an irregular fashion.
- During crushing the rock broke into equiangular fragments but crumbled adjacent to the vugs.

CJ-82-5 Ordovician Stony Mountain Formation-
Gunton Member — Lilyfield Quarry
- 1.8 metres from lower part of Gunton member exposed in north wall of quarry; mottled yellowish and buff grey dolomite.
- Low porosity and no preferred fracture or joint orientation.
- During crushing, the rock tended to break into irregular pieces of various sizes including a high percentage of small fragments indicating the brittle nature of the rock.

CJ-82-6 Ordovician Stony Mountain Formation-
Gunton Member — Stony Mountain
- 4 metres of nodular buff to brownish grey mottled dolomite, base of Gunton Member; sample taken from knoll and south wall — southeast of crusher.
- Rock has a low porosity, is quite massive, and contains no preferred jointing or fracture plains.
- When crushed the rock breaks into equigranular to slightly elongated particles.

CJ-82-7 Ordovician Stony Mountain Formation-
Gunton Member — Lillies Farm Quarry
- 5.5 metres of mottled yellowish and brownish grey dolomite, 1.5 metres above base of Gunton Member; sample taken from north wall along access road.
- The rock is generally massive and ranges from hard to moderately hard and fractures irregularly with a blocky appearances.

CJ-82-8 Ordovician Stony Mountain Formation-
Gunton Member — Gunton Quarry
- Composite 6.85 metre section from east wall and north wall to base of Gunton; mottled nodular dolomite, with four thin layers of burrow-mottled to dense purplish dolomite.
- The rock has a low porosity, is massive, and has no obvious preferred joints or fracture planes.
- When crushed the rock breaks into equiangular to slightly elongated fragments.

CJ-82-9 Ordovician Stony Mountain Formation-
Penitentiary Member — Stony Mountain Quarry
- 2.1 metre section southeast of crusher; mottled pale greenish grey and yellowish orange argillaceous fossiliferous vuggy fragmental dolomite.
- The yellowish orange material is soft, porous, and crumbly with the greenish grey dolomite being slightly harder and not as porous.
- No distinct bedding planes or distinct fracture surfaces were noted.
- The rock fractures in an irregular pattern.

CJ-82-10 Ordovician Stony Mountain Formation-
Gunton Member — Stony Mountain Quarry
1.6 metres of upper part of Gunton Member; in pit northeast of crusher; purplish calcareous shale with three layers (6, 4, and 3 cm) interbedded grey dense limestone.
- The rock is moderately soft, has a low porosity, and the fossil debris is tightly cemented in the carbonate matrix.
- The rock fractures irregularly due to the presence of fossils, has no preferred joint or fracture planes, and when crushed produces a large percentage of rock flour and small fragments.

CJ-82-11 Ordovician Red River Formation-
Fort Garry Member — (Upper)
- 1.5 metres of vuggy, cherty, fragmental mottled dolomite, stratigraphically above red shale marker bed near middle of member; from northwest part of quarry, northeast of Stony Mountain.
- The rock is generally massive with sporadic vugular and pinpoint porosity. Bedding was observed with parting along bedding plane.
- The rock fractures irregularly but in generally blocky fragments and is hard and somewhat brittle.

CJ-82-12 Ordovician Red River Formation-
Fort Garry Member — (Lower)
- 2.5 metres of mainly micritic dolomite, light buff, brittle, and fractured; top of sampled section is 45 cm below the base of the red shale marker bed; from south wall.
- The rock is extremely fine grained, massive, very brittle, and fractures conchoidally although in a rather blocky fashion. The material has a low pinpoint porosity, cherty with thin bedding being observed.

CJ-82-13 Ordovician Red River Formation-
Selkirk Member — Winnipeg Beach
- 4 metres of mottled finely crystalline to granular dolomite, somewhat earthy in lower layers and vuggy in upper part, with dark brown clay patches; northwest corner.
- The rock in general is moderately soft with irregular fracturing and minor pinpoint porosity. Isolated oxidation was observed.

CJ-82-14 Ordovician Red River Formation-
Selkirk Member Garson (Beds A to D)

- South wall of active quarry; 2.7 metres of light buff mottled dolomite limestone, from Tyndall stone beds A to D.
- The rock is medium to coarse grained with isolated distinct calcite crystals. The rock ranges from soft to moderately hard yet is not very brittle.

CJ-82-15 Ordovician Red River Formation-
Selkirk Member Garson (Beds E to H)

- Southeast part of active quarry; 2.8 metres of light grey mottled dolomitic limestone; Tyndall stone beds E to H.
- The rock is medium- to coarse-grained containing large fossils.
- The rock has a low vugular porosity with irregular fracturing and parting along the fractures.

CJ-82-16 Ordovician Red River Formation-
Cat Head Member Riverton

- 3 metres of greyish and brownish buff mottled dolomite, with greyish material being massive, medium grained and hard, and surrounding brownish material being crumbly, with minor pinpoint porosity.
- The rock fractures irregularly and there are no visible bedding planes or fractures.

CJ-82-17 Ordovician Red River Formation-
Dog Head Member Hecla Island

- 3.5 metres of mottled dolomitic limestone in thin flaggy beds, mostly grey core and buff to light brown 1 cm rim.
- Fracturing and parting were observed along existing fracture planes in an irregular fashion. The rock has a medium hardness and is not very brittle.

CJ-83-1 Silurian Cedar Lake Formation (4-7-23-5W)

- 3.6 metres of Silurian Cedar Lake Formation, dolomite from southwest corner of Mulvihill quarry.
- Upper part is laminated light buff reefoid fossiliferous porous dolomite, with thin interlayers of dense finely crystalline dolomite; minor films of green clay.
- Lower part is dense, finely crystalline dolomite, in thin flaggy beds.

CJ-83-2 Devonian Dawson Bay Formation (13-24-10W)

- Slabs of lower limestone, unit B, from outcrops and small quarry.
- Brownish buff fossiliferous microcrystalline limestone, with some argillaceous streaks and purplish red flecks of iron oxide; somewhat brittle.

CJ-83-3 Devonian Winnipegosis Formation (3-21-24-10W)

- From centre of north wall of the Narrows West quarry, 3.6 m of thick to medium bedded, tough, coarsely vuggy, crystalline reefoid dolomite; abundantly fossiliferous, with brachiopods, corals, gastropods, stromatoporoids.

CJ-83-4 Silurian Cedar Lake Formation (NW1/4-19-31-9W)

- From northwest part of quarry north of Fairford.
- 4 m of light buff to cream, brittle micritic dolomite.

CJ-83-5 Ordovician Red River Formation (sec. 22-60-12W)

- From quarry north of Minago River on west side of Highway 6.
- 2.6 m of brownish buff and grey, thin to medium bedded, fairly dense stone.

CJ-83-6 Ordovician Stony Mountain Formation (sec. 2-60-12W)

- From face near centre of quarry, south and east of Minago River and Highway 6.
- 3 m of thin, flaggy brownish buff, bioturbated dolomite; somewhat brittle; fossiliferous, with corals, brachiopods.

CJ-83-7 Silurian Moose Lake Formation (NW1/4-34-48-13W)

- Quarry face in southeast corner of Grand Rapids quarry.
- 6.0 m variably dense micritic to finely crystalline buff dolomite; upper part with abundant stromatolitic layers.

CJ-83-8 Ordovician Red River Formation (SW1/4-30-64-15W)

- Northeast corner of Sunday Lake quarry.
- 5.4 m of tough, dense, nodular dolomite, variably purplish red and olive buff shades. Interval from 1.94 to 2.16 m has scattered coarse vugs. Medium to thick bedded, weathers to thin slabs.

CJ-83-9 Winnipegosis (l.s. 14, 15-9-31-18W)

- Quarry 1.8 km north of Winnipegosis.
- 2 m of Devonian Souris River Formation; Sagemace Member exposed above water table, high-calcium limestone.

CJ-83-10 Devonian Souris River Formation-
Sagemace Member (l.s. 1-5-33-19W)

- 2 m of orange to buff fossiliferous limestone and dolomite exposed along south wall of quarry.
- Limestone is soft, friable, vuggy in part, thick bedded with iron staining throughout.

CJ-83-11

- Precambrian-Archean granite, with minor granodiorite quarry (SE 1/4-33-15-11E).
- Quarry excavated in bedrock outcrop, pink, medium- to coarse-grained granite, much jointing in rock.

CJ-83-12

- Precambrian-Archean tonalite, minor granodiorite, granite, related gneiss.
- 4 m of quarry face exposed above water table, granitic pegmatite veins throughout; sample taken from north wall of quarry (1-18-9E).

APPENDIX III
CHEMICAL ANALYSIS OF BEDROCK SAMPLES

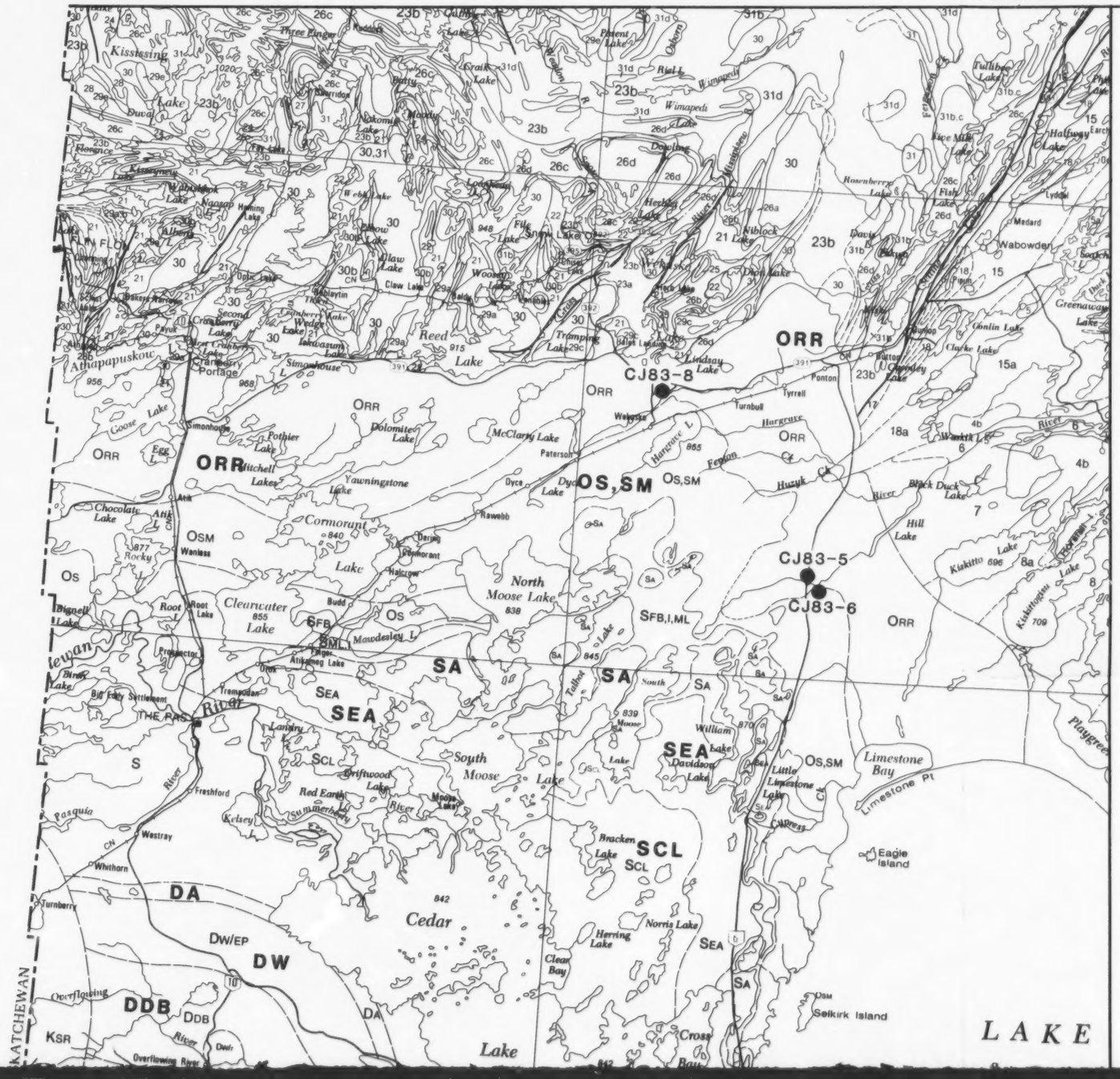
Sample Number Geologic Formation/Member	CJ82-3 Stonewall	CJ82-4 Stonewall	CJ82-5 Stony Mtn., Gunton	CJ82-6 Stony Mtn., Gunton	CJ82-7 Stony Mtn., Gunton	CJ82-8 Stony Mtn., Gunton	CJ82-9 Stony Mtn., Penitentiary	CJ82-10 Stony Mtn. Gunn
SiO_2	0.21	0.34	2.95	1.35	0.78	1.54	12.00	7.70
Al_2O_3	0.11	0.17	1.02	0.39	0.14	0.33	3.94	2.66
Fe_2O_3	0.11	0.16	0.48	0.26	0.21	0.26	2.13	1.54
CaO	31.1	31.2	30.0	30.9	30.5	30.6	26.7	42.5
MgO	20.8	20.7	19.6	20.3	20.4	20.0	18.4	4.90
Na_2O	0.01	0.02	0.03	0.02	0.01	0.01	0.09	0.04
K_2O	0.02	0.05	0.38	0.16	0.06	0.16	1.56	1.05
TiO_2	0.00	0.01	0.05	0.02	0.01	0.02	0.20	0.13
P_2O_5	0.01	0.02	0.01	0.01	0.00	0.01	0.05	0.04
MnO	0.01	0.02	0.03	0.03	0.02	0.02	0.04	0.04
LOI	47.54	47.37	45.51	46.81	47.10	46.55	38.23	38.75
Total	99.92	100.06	100.06	100.25	99.23	99.50	100.34	99.35

CHEMICAL ANALYSIS OF SELECTED ROCK SAMPLES (SILURIAN)

CHEMICAL ANALYSIS OF SELECTED ROCK SAMPLES (DEVONIAN)

Sample Number Geologic Formation/Member	CJ82-1 Inwood	CJ82-2 Inwood	CJ83-1 Cedar Lake	CJ83-4 Cedar Lake	CJ83-7 Moose Lake	CJ83-2 Dawson Bay	CJ83-3 Winnipegosis	CJ83-9 Winnipegosis	CJ83-10 Sagemace
SiO_2	0.09	0.10	0.14	0.17	0.64	2.39	0.08	0.71	5.68
Al_2O_3	0.02	0.07	0.08	0.04	0.12	0.68	0.00	0.16	2.00
Fe_2O_3	0.08	0.13	0.1	0.1	0.19	0.21	0.65	0.07	1.36
CaO	30.4	31.1	31.0	30.7	30.3	52.8	30.80	54.3	30.30
MgO	20.5	20.7	21.9	21.4	21.0	0.55	20.80	0.4	17.50
Na_2O	0.0	0.01	0.03	0.01	0.02	0.02	0.02	0.01	0.12
K_2O	0.0	0.01	0.01	0.04	0.09	0.36	0.00	0.09	0.74
TiO_2	0.0	0.00	0.00	0.01	0.01	0.04	0.00	0.02	0.09
P_2O_5	0.0	0.00	0.01	0.01	0.01	0.04	0.01	0.01	0.07
MnO	0.0	0.01	0.01	0	0	0.02	0.02	0.02	0.05
LOI	47.57	47.56	47.95	47.54	47.18	42.62	47.56	43.63	42.87
Total	98.66	99.69	101.2	100	99.6	99.73	99.94	99.42	100.78

Manitoba
Energy and Mines



MAP AR86-1 LOCATION AND GEOLOGY OF BEDROC

DEVONIAN
- SOURIS RIVER FORMATION (DSR)
- DAWSON BAY FORMATION (DDB)
- ELM POINT FORMATION (DEP)
- WINNIPEGOSIS FORMATION (DW)
- ASHERN FORMATION (DA)

SILURIAN

INTERLAKE GROUP
- FISHER BRANCH (SFB)
- INWOOD (SI)
- MOOSE LAKE (SML)
- ATIKAMEG (SA)
- EAST ARM (SEA)
- CEDAR LAKE (SCL)

ORDOVICIAN
- STONEWALL FORMATION (OS)
- STONY MOUNTAIN FORMATION (OSM)
  - GUNN AND PENITENTIARY MEMBERS(OSMgp)
  - GUNTON AND WILLIAMS MEMBERS (OSMgw)
- RED RIVER FORMATION (ORR)
  - FORT GARRY (ORRfg)
  - SELKIRK (ORRs)
  - DOG HEAD (ORRdh)
  - CAT HEAD (ORRch)

PRECAMBRIAN

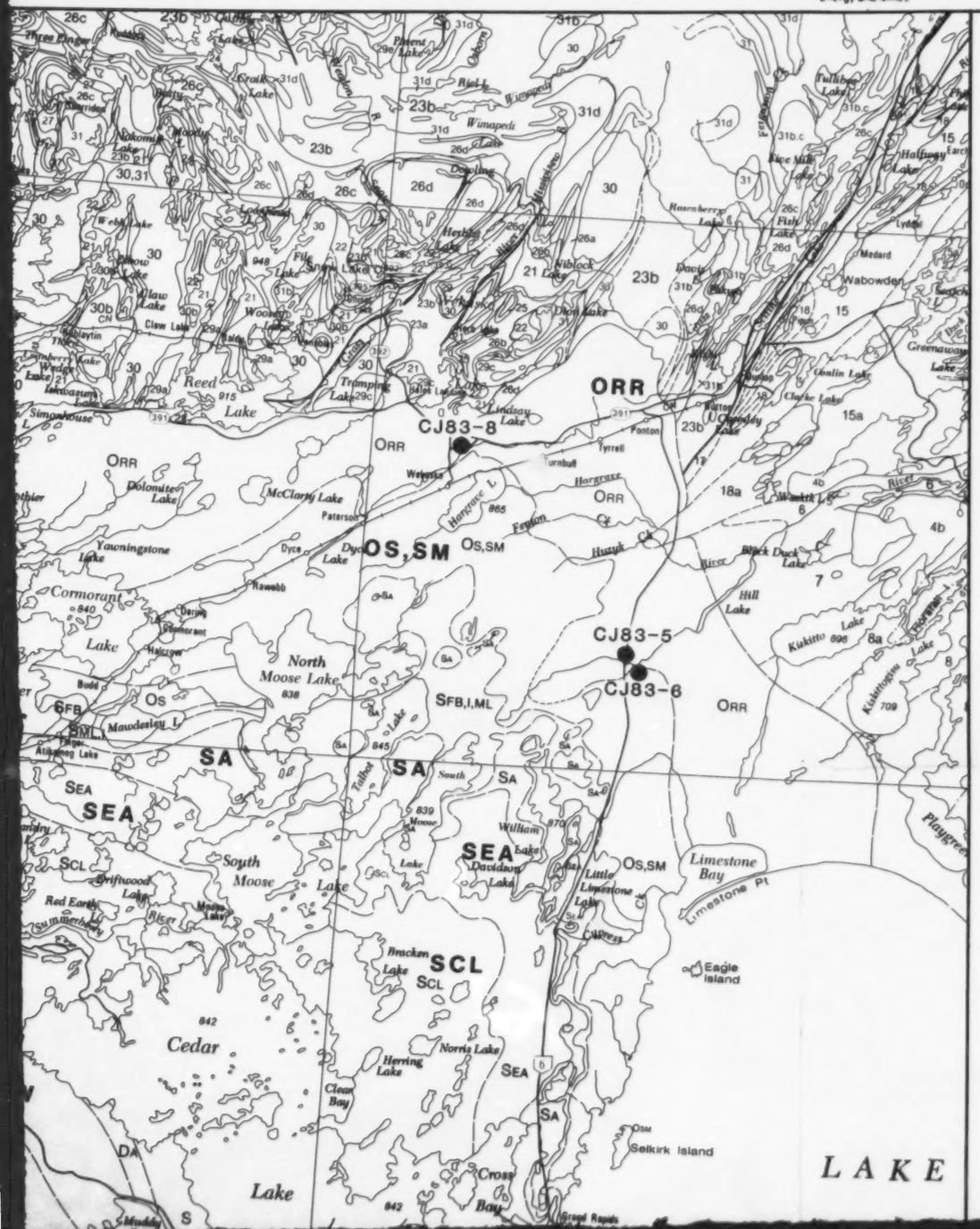
COMPILATION BY CHARLES JONES

LEGEND

● SAMPLE LOCATION

SAMPLE NO.	
CJ82-1	L
CJ82-2	L
CJ82-3	S
CJ82-4	S
CJ82-5	↓
CJ82-6	1
CJ82-7	L
CJ82-8	L
CJ82-9	1
CJ82-10	1
CJ82-11	2
CJ82-12	2
CJ82-13	6
CJ82-14	L
CJ82-15	L
CJ82-16	L
CJ82-17	N
CJ83-1	L
CJ83-2	1
CJ83-3	L
CJ83-4	N
CJ83-5	2
CJ83-6	2
CJ83-7	N
CJ83-8	S
CJ83-9	1
CJ83-10	

Manitoba
Energy and Mines



MAP AR86-1 LOCATION AND GEOLOGY OF BEDROCK SAMPLES

DEVONIAN
- SOURIS RIVER FORMATION (DSR)
- DAWSON BAY FORMATION (DDB)
- ELM POINT FORMATION (DEP)
- WINNIPEGOSIS FORMATION (DW)
- ASHERN FORMATION (DA)

SILURIAN

INTERLAKE GROUP
- FISHER BRANCH (SFB)
- INWOOD (SI)
- MOOSE LAKE (SML)
- ATIKAMEG (SA)
- EAST ARM (SEA)
- CEDAR LAKE (SCL)

ORDOVICIAN
- STONEWALL FORMATION (OS)
- STONY MOUNTAIN FORMATION (OSM)
  - GUNN AND PENITENTIARY MEMBERS(OSMgp)
  - GUNTON AND WILLIAMS MEMBERS (OSMgw)
- RED RIVER FORMATION (ORR)
  - FORT GARRY (ORRfg)
  - SELKIRK (ORRs)
  - DOG HEAD (ORRdh)
  - CAT HEAD (ORRch)

PRECAMBRIAN

COMPILATION BY CHARLES JONES

LEGEND

● SAMPLE LOCATION

SAMPLE NO.	LOCATION
CJ82-1	LS3-11-18-1W
CJ82-2	LS3-11-18-1W
CJ82-3	SEC. 30,31-13-2E
CJ82-4	SEC. 30,31-13-2E
CJ82-5	LS2-28-12-2E
CJ82-6	11-13-2E
CJ82-7	LS13-32-13-2E
CJ82-8	LS6-28-15-2E
CJ82-9	12-13-2E
CJ82-10	14-13-2E
CJ82-11	27-13-3E
CJ82-12	27-13-3E
CJ82-13	6-13-4E
CJ82-14	LS15-3-13-6E
CJ82-15	LS15-3-13-6E
CJ82-16	LS13-22-24-4E
CJ82-17	N1/2-25-25-6E
CJ83-1	LS4-7-23-5W
CJ83-2	13-24-10W
CJ83-3	LS3-21-24-10W
CJ83-4	NW1/4-19-31-9W
CJ83-5	22-60-12W
CJ83-6	2-60-12W
CJ83-7	NW1/4-34-48-13W
CJ83-8	SW1/4-30-64-15W
CJ83-9	LS14,15-9-31-18W
CJ83-10	LS1-5-33-19W

PRECAMBRIAN

COMPILATION BY CHARLES JONES

LEGEND

- ● SAMPLE LOCATION
- —— GEOLOGIC BOUNDARY
- CJ82-1 SAMPLE NUMBER

CJ83-4
CJ83-5
CJ83-6
CJ83-7
CJ83-8
CJ83-9
CJ83-10
CJ83-11
CJ83-12

Scale 1:1 000 000

KILOMETRES 10 0 10 20 30 40 50 60 70 80 90

LAKE WINNIPEGOSIS

LAKE WINNIPEG

SASKATCHEWAN

MANITOBA

DA DW/EP DW DDB KSR DSR SCL SEA SA OSM ORR OS,SM SI KRMm KVR KF KA DEP

CJ83-7 CJ83-10 CJ83-9 CJ83-4 CJ83-3 CJ82-17

Cedar Lake Swan Lake Pelican Lake Waterhen Lake Dawson Bay Red Deer Lake Lake St. Martin Lake Manitoba

Overflowing River Overflowing Bay Muddy Bay Spruce Island Channel Island Cameron Bay Grand Island Denbeigh Point Kanusk L. Kawinaw Lake Katimik Lake Pelican Rapids Pelican Bay Wicked Point McKay L. Soul L. Pickerel Sipib Lake Atim Lake Chitek Lake Dancing Point Reindeer Island Selkirk Island Cross Bay Clear Bay Herring Lake Norris Lake Eagle Island Beaver Dam L. Morrison Lake Grand Rapids Waterville Overflow Bay Cameron Bay Dawson Bay Red Deer Lake Swan River Minitonas Bowsman Woody Turnberry Whithorn Duck Bay Waterhen Lake Salt Point Meadow Portage Crane River Toutes Aides Oak Brae Wooden Moose Bay Marketon Million Magnet East Bay Cayer Dauphin Lake Ochre Beach Ochre River Dauphin River Fairford River Fairford Dam Fairford Reserve Steep Rock Faulkner Grahamdale Spearhill Moosehorn Ashern Lonely Lake Eddystone Ste. Rose du Lac Sherbrook Inwood Gypsumville Meadow Portage Dwr Velva Ethelbert Fishing River Valley River Grandview Gilbert Plains DAUPHIN Shell Valley Birch River Whitefish Lake Swan River Woody Bowsman Minitonas Bowan Durban Roblin Lake of the Prairies Shellmouth Dam Birchview Lennard Pinglet Deepdale Makaroff Lauchie Lake Childs Lake Bogay Creek San Clara McBride Lakes Zelena Mirondale Venlaw Sifton Valley Shortdale Temperton Shevlin Ashville Binscarth Harding Hamiota Oakburn Rossburn Inglewood Watrous Basket Watrous Lake Kyle Bellgate Nowra Armit North Steeprock Lake South Steeprock L. Bell L. Mafeking Red Deer Lake Dawson Bay

PRECAMBRIAN

COMPILATION BY CHARLES JONES

LEGEND

- ● SAMPLE LOCATION
- —— GEOLOGIC BOUNDARY
- CJ82-1 SAMPLE NUMBER

CJ83-4	NW1/4-19-31-9W
CJ83-5	22-60-12W
CJ83-6	2-60-12W
CJ83-7	NW1/4-34-48-13W
CJ83-8	SW1/4-30-64-15W
CJ83-9	LS14,15-9-31-18W
CJ83-10	LS1-5-33-19W
CJ83-11	SE1/4-33-15-11E
CJ83-12	1-18-9E

Scale 1:1 000 000

KILOMETRES 10 0 10 20 30 40 50 60 70 80 90 100 KILOMETRES

LAKE WINNIPEGOSIS

LAKE WINNIPEG

ORR

SILURIAN

DEVONIAN

CJ83-7 CJ83-10 CJ83-9 CJ83-4 CJ83-3 CJ82-17

52°

DEVONIAN

JURASSIC

CRETACEOUS

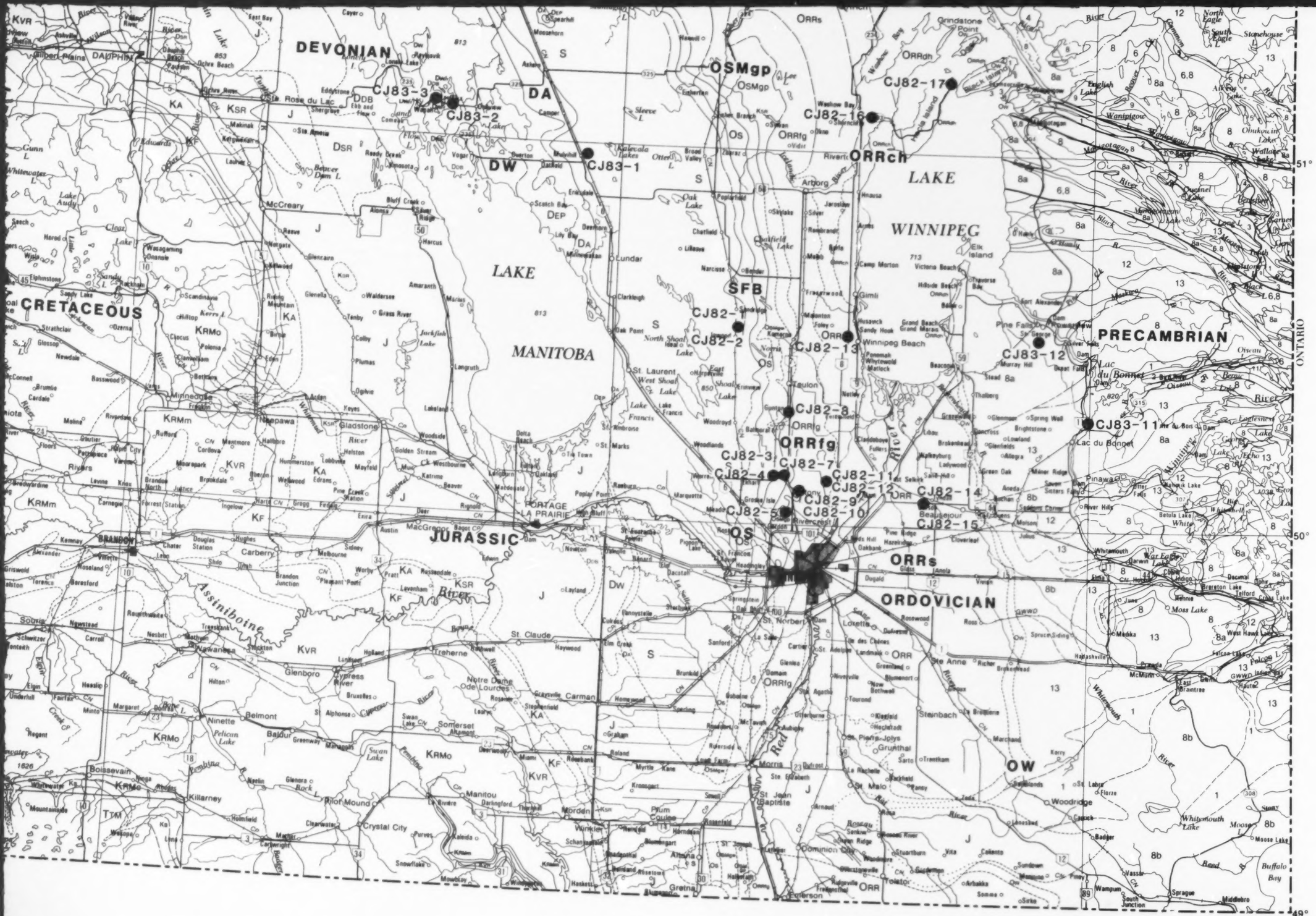
ORDOVICIAN

LAKE WINNIPEG

LAKE MANITOBA

CJ83-3
CJ83-2
CJ83-1
CJ82-17
CJ82-16
CJ82-1
CJ82-2
CJ82-13
CJ83-12
CJ82-8
CJ82-3
CJ82-7
CJ82-4
CJ82-11
CJ82-12
CJ82-14
CJ82-9
CJ82-10
CJ82-5
CJ82-15

DA
DW
DEP
OSMgp
ORRch
SFB
ORRs
ORRfg
ORR
OS
KSR
KF
KA
KRMo
KRMm
KVR
KRM
TTM
DSR
DDB


DEVONIAN
CRETACEOUS
JURASSIC
ORDOVICIAN
PRECAMBRIAN
LAKE
WINNIPEG
MANITOBA
ONTARIO
CJ83-3
CJ83-2
CJ83-1
CJ82-1
CJ82-2
CJ82-3
CJ82-4
CJ82-5
CJ82-7
CJ82-8
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CJ82-17
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CJ83-12
DA
DW
DSR
DEP
SFB
OSMgp
ORRch
ORRfg
ORRs
ORR
OS
OW
KA
KSR
KF
KRMo
KRMm
KVR
TM
Brandon
Portage La Prairie
Steinbach
Winnipeg Beach
Lac du Bonnet
Pinawa
Assiniboine River
Red River
Whitemouth River
Winnipeg River
51°
50°
49°